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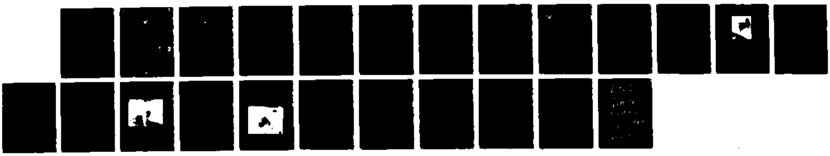

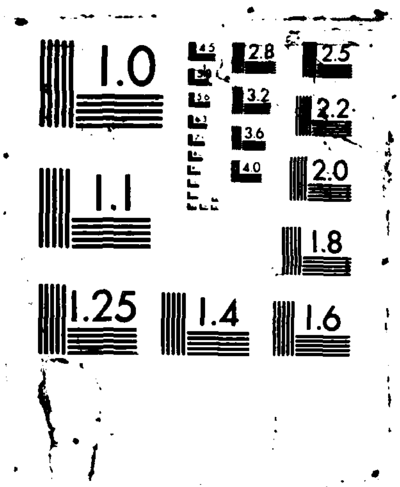
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AIR COMMAND AND STAFF COLLEGE

STUDENT REPORT

NAVSTAR GLOBAL POSITIONING SYSTEM

MAJOR RUDOLPH T. SCHWAB 88-2355

"insights into tomorrow"

REPORT NUMBER 88-2355
TITLE NAVSTAR GLOBAL POSITIONING SYSTEM

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The NAVSTAR Global Positioning System (GPS) is an all-weather, jam-resistant, continuous-operation, space-based, passive radio navigation and positioning system. The GPS consists of three segments: the Space Segment, the Control Segment, and the User Segment. The United States Armed Forces will purchase over 20,000 GPS user sets, with the US Army buying 6,000 sets. This article for publication will provide the Army soldier with an understanding of the capabilities and limitations of GPS. The article includes a short history on why GPS was developed, discusses the three GPS segments, and provides examples on how GPS will enhance US Army operations.

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PREFACE

To fight the next battle outnumbered and win, the US Army must understand and use the capabilities provided by space systems. This article provides the Army soldier with the history, composition, and capabilities of such a system, the NAVSTAR Global Positioning System. Additionally, this paper will clarify several misconceptions the Army community may have about GPS.

Subject to clearance, this article will be submitted to the Army Aviation Association of America magazine or the Army Magazine for consideration.

The author hopes this article will be incorporated into the ACSC Space Phase of instruction.

ABOUT THE AUTHOR

Major Rudolph T. Schwab graduated from the United States Military Academy in 1973 with a bachelor of science degree and from the Naval Postgraduate School in 1983 with a Master of Science Degree in Aeronautical Engineering.

He was commissioned as a 2LT in the Armor branch of the United States Army. He served as an Armor platoon leader and company executive officer in Germany. He later branch transferred to Aviation and served in the 82nd Airborne Division as a service platoon leader, troop executive officer, and squadron S-2. In 1983, he was assigned to the US Army Aviation Systems Command, St Louis, MO, where he worked in the Office of the Program Manager, COBRA, and later, as assistant secretary of the general staff for research and development. In 1985, he was assigned for one year to Air Force Space Command, Colorado Springs, CO, as a NAVSTAR Global Positioning System staff officer. After a year, he continued working on space matters for the US Army Space Agency.

He has completed the resident Armor Officer Basic and Advance Course and the Army Command and General Staff College non-resident program.

In 1986 and 1987, he was nominated by the US Army to NASA as an Army astronaut mission specialist candidate.

His thesis, "Computer Program Analysis of Helicopter Weight Estimate Relationships Utilizing Parametric Equations," was published in June 1985, and has been footnoted in a published book on helicopter design. He published an article in the January 1985 edition of the Army Aviation Association of America magazine entitled, "COBRA: Evolution of the Attack Helicopter." In March 1987, he edited and distributed throughout the Army space community a pamphlet titled, "Commander's Handbook of Space Systems for Support of Army Forces."

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

EXECUTIVE SUMMARY

REPORT NUMBER 88-2355

AUTHOR(S) MAJOR RUDOLPH T. SCHWAB, USA

TITLE NAVSTAR GLOBAL POSITIONING SYSTEM

I. Purpose: To provide the US Army soldier with an understanding of the capabilities and limitations of the NAVSTAR Global Positioning System (GPS).

II. Problem: To fight the next battle outnumbered and win, the US Army must understand the use and capabilities of space assets. The Under Secretary of Defense has stated that GPS will be the Armed Services and Department of Defense position/navigation system of tomorrow. NAVSTAR GPS, when fully operational, will provide the soldier with precise position/navigation accuracy to within eight meters. However, a lack of understanding by the Army community of GPS capabilities has created reluctance to accept this space system as a primary means of position/navigation.

III. Data: Space systems play a vital role in military operations by providing communications, reconnaissance, surveillance, weather, geodesy, and navigation. The battle of tomorrow will be fought by joint forces relying heavily on the capabilities provided by satellites. The NAVSTAR GPS

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will provide units with not only precise position/navigation information, but also, with worldwide common grid and precise time. Since GPS will become the standard position/navigation aid in the Department of Defense, the Army needs to increase its awareness of this system. An article written by an Army GPS expert should add credibility to this subject while providing the first step towards improving the Army's awareness of space assets. The author's expert knowledge of the GPS program and complete understanding of misconceptions within the Army community are the basis for this article.

NAVSTAR GLOBAL POSITIONING SYSTEM

> "The pace of battle in future conflict will demand that combat commanders be able to precisely locate themselves and other friendly units."
>
> General (Ret) Donald Keith
> Commander, Army Materiel Command
> The New High Ground

On 24 April 1980, eight helicopters departed the USS Nimitz enroute to rescue American hostages in Tehran, Iran. Shortly after takeoff, one helicopter aborted due to maintenance problems. Only six helicopters were needed for mission accomplishment, therefore, the remainder proceeded on course. Soon, the pilots encountered clouds of fine dust that created navigation difficulties and caused them to fly on instruments. Later, two more helicopters had equipment failures, thus the mission was aborted. One of these helicopters lost its radio navigation equipment and was not able to navigate on instruments or across a distant 9000-foot mountain. Had a NAVSTAR Global Positioning System (GPS) receiver been installed, the helicopter could have easily navigated through the dust storm and across the mountains. (2:124-125)

This is just one example of a military tactical operation that failed due to the inability to navigate. Even today, soldiers have difficulty navigating in US training areas such as Yakima, National Training Center, or Pinon Canyon Maneuver Site. If we can't navigate over terrain where we constantly train, how will we navigate on foreign soil during combat? The answer is the NAVSTAR GPS, a space system that will revolutionize future military operations. The NAVSTAR GPS is an all-weather, jam-resistant, continuous-operation, space-based, passive radio navigation and positioning system. GPS will provide worldwide military users with 8-meter position accuracy, velocity to 0.1 meters per second, and time synchronization to 0.1 microseconds. (5:2)

This article will provide a basic understanding of the capabilities of GPS, while clarifying several misconceptions the Army user community may have about this space system.

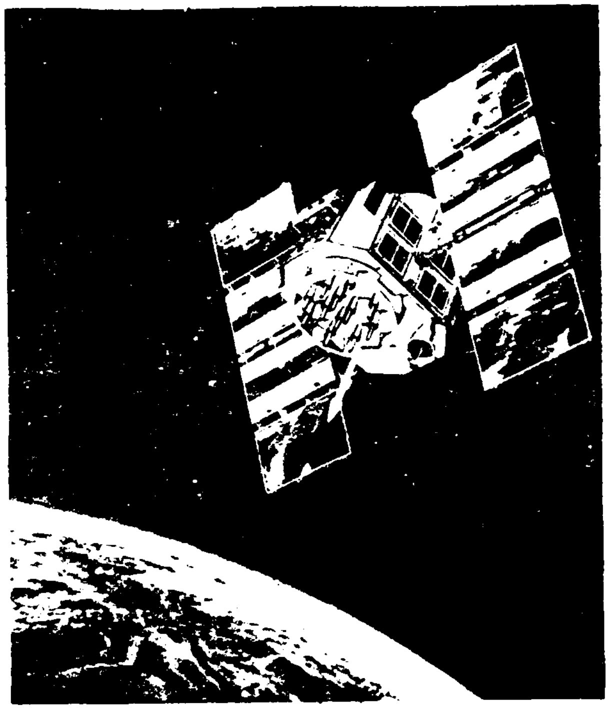

Figure 1. NAVSTAR GPS Block II Satellite (1:12-7)

System History

Since the early 1960s, the Navy and Air Force have conducted extensive research on the concept that navigation could be performed using radio signals from satellites. In 1964, the Navy TRANSIT satellite program became operational and provided intermittent worldwide maritime navigation for the Fleet Ballistic Missile Submarine force. TRANSIT system accuracy was dependent on the user knowing his velocity. A velocity error of 0.5 knots resulted in a position error of 600 feet. (2:130-131) During the late 1960s, the Navy, attempting to improve TRANSIT accuracy, initiated the program TIMATION. The specific purpose of this program was to conduct research to advance the development of high stability oscillators (clocks) and time transfer techniques for two-dimensional (latitude and longitude) satellite navigation. Concurrently, the Air Force conducted feasibility studies for a three-dimensional (latitude, longitude, and altitude) system called System 621B. (8:2-5)

On 17 April 1973, the Deputy Secretary of Defense (DEPSECDEF) directed the combination of the best features of the TRANSIT, System 621B, and TIMATION activities into one program designated NAVSTAR GPS. The DEPSECDEF designated the Air Force as lead service for program development. The GPS Joint Program Office (JPO) was established at Los Angeles Air Force Station, California, with representatives from all the armed services, Coast Guard, Defense Mapping Agency, Department of Transportation, and NATO. The system was designed with three segments: Space Segment, Control Segment, and User Segment. (5:14,16)

Space Segment

On 22 February 1978, Space Segment deployment began with the launch of the first of 11 research and development (R&D) satellites, commonly referred to as Block I satellites. These satellites were designed for testing the GPS user equipment. To support this testing the satellites were placed in orbits that would provide maximum daily coverage over the test area at Yuma, Arizona. Of the 11 R&D satellites launched, seven remain operational today. (11:4A)

When fully operational in 1991, the Space Segment will consist of a constellation of 21 satellites (Figure 2), known as Block II satellites, with a design life of 7.5 years. The satellites will orbit the earth once every 12 hours at an altitude of 10,898 nautical miles and will be in six evenly spaced planes. Each plane will have three satellites evenly spaced; alternating planes will have four satellites.

To increase satellite survivability against potential threats, countermeasures were incorporated into the satellite design. Threats include "anti-satellite weapons, high-powered directed-energy laser sources, and particle beam weapons." (5:4) The spacing of the satellites and their continuous movement makes targeting by these type weapons difficult. To counter the jamming and spoofing threat, the satellite signals were encrypted.

Throughout the Army community there has been discussion that three of the satellites are spares and can be moved anywhere in space. This is not true. In 1981, Congress cut the program approximately $500 million. This reduced the originally planned constellation of 24 satellites to the current 21 satellite constellation of which 3 were to be on-orbit spares. (8:17-18) These so-called spares were necessary to insure at least 18 satellites would be operational 98% of the time. (7:7) The spares were initially to be placed in orbit in the "turned off" mode. However, testing revealed that the life of the satellites would start to deteriorate once placed in orbit whether the satellites were "turned on" or "off." Therefore, the GPS JPO decided to integrate the three spares, "turned on", into the constellation in such a way as to maximize coverage over the United States.

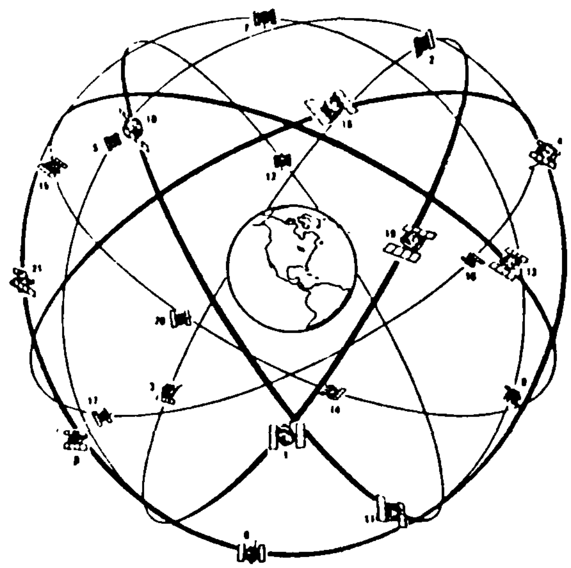

Figure 2. NAVSTAR GPS Block II Constellation (10:11)

Another misconception is that the GPS constellation does not provide 24-hour, continuous, three-dimensional coverage. This is not true. However, due to satellite geometry within the constellation, (Position Dilution of Precision), there are areas throughout the world where accuracy is degraded beyond eight meters. These areas are predictable and the United States Space Command (USSPACECOM) is developing a reporting system to provide this information to users. Additionally, USSPACECOM is evaluating the requirement to increase the constellation to 24 satellites which would eliminate these areas of degraded accuracy.

Control Segment

The Control Segment provides satellite telemetry, tracking, and commanding. It consists of five monitor stations (MSs), three ground antennas (GAs), and a master control station (MCS). The MSs are located in Hawaii, Ascension Island, Diego Garcia, Kwajalein Atoll, and Colorado Springs, CO.

The MSs passively track each satellite and collect ranging data from the navigation signals. This information is transmitted to the MCS (satellite operations center), located 10 miles east of Colorado Springs, where it is processed to determine orbital position error associated with each satellite. Air Force personnel at the MCS correct the data and transmit the corrected data to the satellites via the GAs located on Ascension, Diego Garcia, and Kwajalein. To maintain system accuracy this procedure occurs three times daily.

To increase survivability the Control Segment was located on military facilities. Redundant MSs and GAs were built to insure that destruction of one station would not impact system operations or performance. (5:4)

User Segment

The User Segment consists of three types of user sets (satellite receivers): one-channel, two-channel, and five-channel. The Army is procuring the one-channel set for manpack and vehicle mounted and the two-channel set for the helicopter. The five-channel will be used by the Navy and Air Force.

The user sets are passive. Navigation/position data from the satellite can be automatically obtained by simply turning on the set. The satellites transmit a navigation message that provides the user set with the exact position of all satellites in the constellation. Ranges to the satellites are determined by multiplying the transmit time from the satellite to the user set, by the speed of light (Distance = Transmit Time * Speed of Light). (3:3) Since the satellites use atomic clocks and the user set uses a crystal clock, these range measurements have an error associated with the user set clock. Therefore, to provide a three-dimensional navigation solution, the GPS user set must acquire signals from four satellites simultaneously, to solve the four unknowns: latitude, longitude, altitude, and time. (4:74)

This process is very similar to locating your unknown position on a tactical map using resection techniques. Think of the satellites as church steeples in the distance, and you are trying to find your location with a map and compass. You take a back azimuth from each steeple, draw these lines on the map, and the intersection of the lines is your location. Similarly, the satellites transmit their location to the user set. By receiving signals from four satellites the set completes a three-dimensional resection.

Figure 3. GPS Manpack

Below, Figure 4 compares GPS navigation characteristics to that of current navigation systems, while Figure 5 graphically depicts system accuracies.

System	Position Accuracy (meters)	Velocity Accuracy (meters/sec)	Range of Operation	Comments
GPS	8	.1	Worldwide	Operational worldwide with 24-hour all-weather coverage. Unlimited users. Jam resistant.
Loran-C	180	No velocity data	US Coast, Conus, Selected Overseas Areas	Operational with localized coverage. Limited by skywave interference.
Omega	2200	No velocity data	Worldwide	Operational worldwide with 24-hour coverage. System is subject to Very Low Frequency (VLF) propagation.
Platform INS	1500 max after 1st hour	0.8 after 2 hours	Worldwide	Operational worldwide with 24-hour all-weather coverage. Degraded performance in polar regions.
TACAN	400	No velocity data	Line of sight (present air routes)	Position accuracy is degraded mainly because of azimuth uncertainty which is typically on the order of ± 1.0 degree.
TRANSIT	200	No velocity data	Worldwide	The interval between position fixes is about 90 minutes. For use in slow moving vehicles. Better position accuracy is available with dual frequency measurements.

Figure 4. Navigation System Comparison (12:slide)

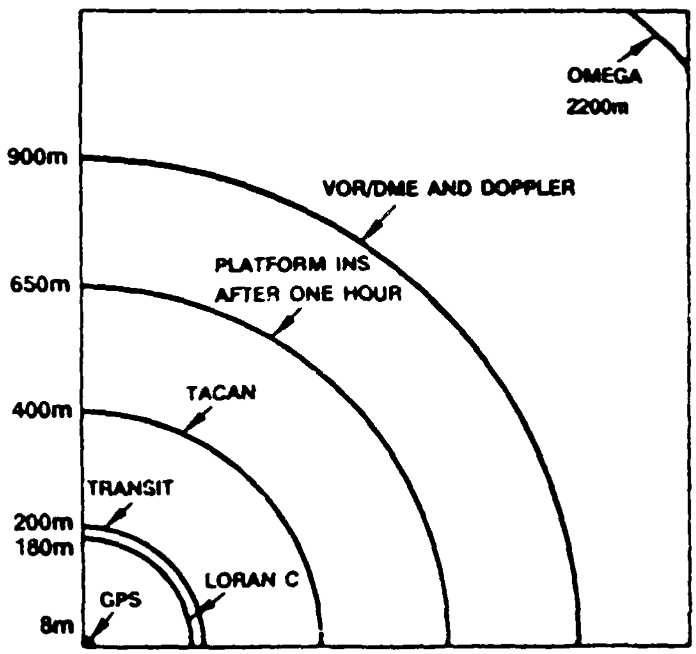

Figure 5. Navigation System Accuracies (5:5)

GPS will provide the user with more than just precise position, time, and velocity. The user set will provide additional information upon interrogation by the user. A handheld Computer Display Unit (CDU) for the manpack and console-mounted CDU for the helicopter display this information. Since the two-channel helicopter set is integrated into on-board navigation systems, GPS functions are basically transparent to the pilot. The set can display position in latitude-longitude or 10-digit coordinates. Ten waypoints for the manpack and 200 waypoints for the two-channel can be stored in memory. The set also provides steering commands and distance to any waypoint selected. The set calculates direction-of-travel to .1 degree and velocity in either kilometers or miles per hour. The user can also input distance and direction to a target and the user set will compute the target's location.

Figure 6. GPS Manpack CDU

GPS user sets were designed to be highly jam resistant and electromagnetic pulse (EMP) hardened. Spread spectrum satellite signals tremendously increase jam resistance, while the passive design of the set makes it impossible for the enemy to locate.

However, there is concern by some Training and Doctrine Command (TRADOC) schools that the GPS signal cannot penetrate dense foilage. This deficiency surfaced during initial operational tests and has been corrected. In March 1987, I operated a manpack inside an armor battalion tactical operations center, consisting of three M-577s with tent extensions. The battalion radios, generators, tent, and camoflage nets had no impact on the GPS signals or set performance. The set accuracy was determined as eight meters. Additionally, I have operated a manpack on the first floor of a two-story wood building and experienced no degradation of set performance. However, should signal interference occur, the set will display a code informing the user of this condition and will also provide estimated position error.

System/Equipment Availability

Beginning in early 1990, GPS satellites will provide worldwide two-dimensional coverage. By mid 1991, GPS worldwide coverage will be three-dimensional. (11:3A) Limited fielding of user equipment will begin in 1989 with full-scale fielding beginning in late 1991. (9:1) TRADOC proponents have validated use of GPS by these type units: Infantry, Field Artillery, Aviation, Air Defense Artillery, Transportation, Intelligence and Electronic Warfare (IEW), Special Forces, and Signal Corps. (6:Appendix)

Military Applications

GPS capabilities will enhance future military operations by providing precise position, navigation, and time sychronization to the soldier. Enhanced location accuracy, increased first round call-for-fire accuracy, precise minefield and obstacle emplacement, and all-weather, cross-country navigation are just a few examples of how GPS will impact on military operations.

GPS will give the commander tremendous flexibility in using map graphics control measures. Identifiable terrain will no longer be the primary factor in determining control measures, coordination points, or even passage-of-lines entrance. Forces will have the ability to link-up in the middle of a forest at night, thus increasing security of the forces and concealment from the enemy. Entry points used in passage-of-lines will be easily and quickly located, while quartering parties will no longer have difficulty finding new assembly areas or the release point on foggy nights.

First round accuracy will be improved through accurate emplacement of artillery, coupled with precise enemy location information provided by the Forward Observer (FO). An artillery battery on the move will have the benefit of continuous 8-meter position and 0.1-degree direction-of-travel accuracy. Additionally, the FO will be able to precisely locate his position and the enemy's. By inputting the azimuth and distance to the target, the FO will obtain a 10-digit coordinate for the enemy's location.

Armor units will be able to travel high-speed, cross-country at night, buttoned-up, and still know their position continously to within eight meters. Tanks will also be able to move into defilade and set their azimuth indicator to direction of travel provided by GPS. The tank commander, using his laser range finder and direction-of-travel data from GPS, can input this information into the set to determine precise enemy location.

Pilot workload during nap-of-the-earth operations will be decreased since GPS will provide exact location, allowing the pilot more "head out of the cockpit" time. Landing zones and forward area ammunition and refuel points can be quickly and accurately located at night, saving precious time and fuel. This system is so accurate that during operational system tests, a GPS-equipped BLACK HAWK helicopter executed a successful, planned, hooded approach to the top of a water tower. Air corridors of any size or length and up to 200 waypoints can be programmed into the GPS set. The set will tell you when you are outside the corridor or when you have reached or passed a waypoint. By not violating specified air corridors while transiting friendly lines, aircraft survivability will be increased due to fewer engagements by friendly air defense units. Precise location, velocity, and time information will be fed to the fire control systems on the COBRA and APACHE helicopters, thus increasing their weapons delivery accuracy. Aviators will become the biggest user of GPS in the future, since GPS will become the primary enroute navigation aid replacing ADF, VOR, OMEGA, LORAN-C, and TACAN.

Logistics personnel will also benefit from the position/navigation accuracy offered by GPS. Executive officers, first sergeants, and G-4/S-4 personnel will no longer spend excessive time and fuel providing logistical support to their units. Truck drivers, M-88 operators, and 2LTs will always know their location. GPS will also provide medics with the ability to expeditiously locate wounded and assist in timely evacuation to the aid station.

Any unit employing GPS will benefit from precise position/navigation information. Engineers will finally have the ability to accurately emplace minefields or obstacles in any weather, at night, and without regard to identifiable terrain such as crossroads. IEW units will use GPS for precise positioning of intelligence gathering assets and for electronic warfare aircraft navigation. Special Forces units will have improved capability to conduct operations in regions with limited tactical map coverage or in areas where terrain makes navigation extremely difficult, such as the desert or jungle. The Signal Corps plans to use GPS to emplace the master control net of the Army's Position Location Reporting System, while watercraft units from the Transportation Corps will use this system for inland waterway navigation.

With GPS, for the first time in history, the soldier will have highly precise, continuous-operation, all-weather, position/navigation information. Fuel, time, lives, and battles will be saved because soldiers will no longer get lost or wander across enemy lines, all thanks to GPS. To be an effective fighting force in the future, the Army must be prepared to conduct joint air-land operations anywhere in the world. The common grid and precise time reference provided by GPS will insure all forces are "reading off the same sheet of music." Superior technology can play a vital role in reducing the odds on the battlefield. History demonstrates the great battles were won by those armies with the foresight and initiative to employ new technology: the long-bow at Hastings, the machine gun and tank in World War I, and the atomic bomb in World War II. NAVSTAR GPS and space-based communication, surveillance, and target acquisition systems, are technologies of the future that will give the commander a decisive edge needed to fight the next battle against a numerically superior opponent and win

> "We, the United States of America, can be first. If we do not expend the thought, the effort, and the money required, then another and more progressive nation will. It will dominate space, and it will dominate the world."

General James H. Doolittle (1959)
Air Force Manual 1-6

BIBLIOGRAPHY

A. REFERENCES CITED

Books

1. Cochran, Curtis, D., Lt Col, USAF, et al (eds). Space Handbook, 12th revision. Maxwell AFB, AL: Air University Press, 1985.

2. Karas, Thomas. The New High Ground. New York: Simon and Schuster, 1983.

Articles

3. Milliken, R. J. and C. J. Zoller. "Principle of Operation of NAVSTAR and System Characteristics." Global Positioning System, Vol 1 (1980), pp. 3-14.

4. Russell, S. S. "Control Segment and User Performance." Global Positioning System, Vol 1 (1980), pp. 74-86.

Official Documents

5. US Air Force Systems Command. NAVSTAR GPS User's Overview. Document No. YEE-82-009B. Los Angeles Air Force Station, California: Air Force Space Division, September 1986.

6. US Army Training and Doctrine Command. The Army Position and Navigation Master Plan. Document No. ACN 31794. Fort Leavenworth, Kansas: US Army Combined Arms Combat Developments Activity, May 1986.

7. US Department of the Air Force. Program Management Directive for the NAVSTAR Global Positioning System (U). PMD Number: R/S 4075(18)/PE 64778F/35164F/35165F. Washington, DC: HQ USAF/RDST, 20 September 1982. SECRET--NATIONAL SECURITY INFORMATION. Classified by Navstar GPS SCG, 29 March 1982. Review on 1 December 1999.

CONTINUED

Unpublished Materials

8. Alford, Dennis, Maj, USAF. "History of the NAVSTAR Global Positioning System." Research study prepared at the Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama, 1986.

9. Schwab, Rudolph T., Maj, USA, (ed). "Commander's Handbook of Space Systems for Support of Army Forces." Pamphlet prepared at the US Army Space Agency, Peterson Air Force Base, Colorado, 12 March 1987.

10. US Department of the Air Force: HQ Air Force Space Command (XPSS). "NAVSTAR Global Positioning System Overview," briefing slides. Peterson Air Force Base, Colorado, February 1986.

11. US Department of the Air Force: HQ Air Force Space Division (YE). "Navstar GPS: Revolution in Space," briefing slides. Los Angeles Air Force Station, California, 5 January 1988.

12. US Department of Defense: HQ United States Space Command (J5S). "US Space Command Overview," briefing slides. Peterson Air Force Base, Colorado, May 1987.

B. RELATED SOURCES

Books

Deudney, Daniel. Space: The High Frontier in Perspective. Washington, DC: Worldwatch Institute, 1982.

Downey, Arthur J., Col, USA. The US Army in Space. Washington, DC: National Defense University Press, 1985.

Gray, Colin S. American Military Space Policy. Cambridge, MA: Abt Associates, 1982.

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